Introduction to Database Systems

Queries in SQL

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The `select` Statement (Basic Version)

- Query statements in SQL start with the keyword

  `select`

  and return a result in table form

  `select` *Attribute* … *Attribute*
  `from` *Table* … *Table*
  [`where` *Condition*]

- The three parts are usually called
  - target list
  - from clause
  - where clause

MotherChild

mother	child
Lisa	Mary
Lisa	Greg
Anne	Kim
Anne	Phil
Mary	Andy
Mary	Rob

FatherChild

father	child
Steve	Frank
Greg	Kim
Greg	Phil
Frank	Andy
Frank	Rob

Person

name	age	income
Andy	27	21
Rob	25	15
Mary	55	42
Anne	50	35
Phil	26	30
Greg	50	40
Frank	60	20
Kim	30	41
Mike	85	35
Lisa	75	87

Selection and Projection

Name and income of persons that are less than 30:

$$\pi_{\text{name, income}}(\sigma_{\text{age<30}}(\text{Person}))$$

```
select name, income
from   person
where  age < 30
```

name	income
Andy	21
Rob	15
Phil	30

Naming Conventions

- To avoid ambiguities, every attribute name has two components

RelationName.AttributeName

- When there is no ambiguity, onecan drop the initial component

RelationName.

```
select person.name, person.income
from   person
where  person.age < 30

can be written as:

select name, income
from   person
where  age < 30
```


`select`: Abbreviations

```
select name, income
from   person
where  age < 30
```

is an abbreviation for:

```
select person.name, person.income
from   person
where  person.age < 30
```

and also for:

```
select p.name as name,  p.income as income
from   person p
where  p.age < 30
```

Two Kinds of Projection

Surname and branch of all employees

employee

empNo	surname	branch	salary
7309	Black	York	55
5998	Black	Glasgow	64
9553	Brown	London	44
5698	Brown	London	64

$\pi_{\text{surname, branch}}$ (employee)

Two Kinds of Projection

```
select
       surname, branch
from employee
```

surname	branch
Black	York
Black	Glasgow
Brown	London
Brown	London

```
select distinct
       surname, branch
from employee
```

surname	ranch
Black	York
Black	Glasgow
Brown	London

Usage of "as" in `select` Statements

"as" in the list of attributes specifies explicitly a name for the attributes of the result. If for some attribute "as" is missing, the name is equal to the one that appears in the list.

Example:

```
select name as personName, income as salary
from   person
where  age < 30
```

returns as result a relation with two attributes, the first having the name `personName` and the second having the name `salary`

```
select name, income
from   person
where  age < 30
```

returns as result a relation with two attributes, the first having the name `name` and the second having the name `income`

Exercise 1

"From the table `person`, compute a new table by selecting only the persons with an income between 20 and 30, and adding an attribute that has, for every tuple, the same value as `income`.

Show the result of the query"

person	name	age	income

Exercise 1: Solution

```
select name, age, income,
       income as also-income
from   person
where  income >= 20 and income <= 30
```

name	age	income	also-income
Andy	27	21	21
Phil	26	30	30
Frank	60	20	20

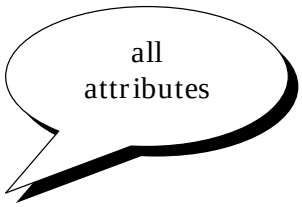
Selection, without Projection

name, age and income of persons younger than 30:

$$\sigma_{age<30}(person)$$

```
select *
from   person
where  age < 30
```

is an abbreviation for:




```
select name, age, income
from   person
where  age < 30
```

`select` with Asterisk

Given a relation R with attributes A, B, C

```
select  *
from    R
where   cond
```

is equivalent to

```
select A, B, C
from   R
where  cond
```


Projection without Selection

name and income of all persons

$$\pi_{\text{name, income}}(\text{person})$$

```
select name, income
from   person
```

is an abbreviation for:

```
select p.name, p.income
from   person p
where  true
```

Expressions in the Target List

```
select income/4 as quarterlyIncome
from   person
where  name = ‘Greg'
```

Complex Conditions in the “where” Clause

```
select *
from   person
where  income > 25
       and (age < 30 or age > 60)
```


The “like” Condition

The persons having a name that starts with 'A' and has a 'd' as the third letter:

```
select *
from   person
where  name like 'A_d%‘
```

- ‘_‘ matches a single letter
- %‘ matches a string

Handling of Null Values

Employees whose age is or could be greater than 40:

$$\sigma_{\text{age} > 40 \text{ OR age IS NULL}} (\text{Employee})$$

```
select *
from   employee
where  age > 40 or age is null
```


Exercise 2

"From the table `employee`, calculate a new table by selecting only employees from the London and Glasgow branches, projecting the data on the attribute `salary`, and adding an attribute that has, for every tuple, twice the value of the attribute `salary`.

Show the result of the query"

employee

empNo	surname	branch	salary

Exercise 2: Solution

```
select salary,
       salary*2 as doubleSalary
from   employee
where  branch = ‘Glasgow' or
       branch = ‘London'
```

salary	doubleSalary
64	128
44	88
64	128

Selection, Projection, and Join

- Using `select` statements with a single relation in the `from` clause we can realise:
  - selections,
  - projections,
  - renamings
- `Joins` (and cartesian products) are realised by using two or more relations in the `from` clause

SQL and Relational Algebra

Given the relations: R1(A1,A2) and R2(A3,A4)

the semantics of the query

```
select R1.A1, R2.A4
from   R1, R2
where  R1.A2 = R2.A3
```

can be described in terms of
- cartesian product (`from`)
- selection (`where`)
- projection (`select`)

Note: This does not mean that the system really calculates the cartesian product!

SQL and Relational Algebra (cntd)

Given the relations: R1(A1,A2) and R2(A3,A4),

```
select R1.A1, R2.A4
from   R1, R2
where  R1.A2 = R2.A3
```

corresponds to:

$$\pi_{A1,A4} (\sigma_{A2=A3} (R1 \times R2))$$

SQL and Relational Algebra (cntd)

It may be necessary to rename attributes

- in the target list (as in relational algebra)
- in the cartesian product (in particular, when the query refers twice to the same table)

```
select X.A1 as B1, …
from   R1 X, R2 Y, R1 Z
where  X.A2 = Y.A3 and …
```

which can also be written as

```
select X.A1 as B1, …
from   R1 as X, R2 as Y, R1 as Z
where  X.A2 = Y.A3 and …
```


SQL and Relational Algebra (cntd)

```
select X.A1 as B1, Y.A4 as B2
from   R1 X, R2 Y, R1 Z
where  X.A2 = Y.A3 and Y.A4 = Z.A1
```

$X \leftarrow R1, Y \leftarrow R2, Z \leftarrow R1,$

$\rho_{B1 \leftarrow X.A1,\ B2 \leftarrow Y.A4}$ (

$\pi_{X.A1,Y.A4}$ ($\sigma_{X.A2 = Y.A3 \text{ and } Y.A4 = Z.A1}$(X x Y x Z)))

MotherChild

mother	child
Lisa	Mary
Lisa	Greg
Anne	Kim
Anne	Phil
Mary	Andy
Mary	Rob

FatherChild

father	child
Steve	Frank
Greg	Kim
Greg	Phil
Frank	Andy
Frank	Rob

Person

name	age	income
Andy	27	21
Rob	25	15
Mary	55	42
Anne	50	35
Phil	26	30
Greg	50	40
Frank	60	20
Kim	30	41
Mike	85	35
Lisa	75	87

Exercise 3

"The fathers of persons who earn more than 20K"

Write the query both in relational algebra and SQL

Exercise 3: Solution

"The fathers of persons who earn more than 20K"

$\pi_{father}(fatherChild \bowtie_{child=name} \sigma_{income>20}(person))$

```
select distinct fc.father
from   person p, fatherChild fc
where  fc.child = p.name
       and p.income > 20
```


Exercise 4: Join

"Father and mother of every person"

Write the query both in relational algebra and SQL

Exercise 4: Solution

"Father and mother of every person"

Can be calculated in relational algebra by means of a natural join

$$\text{fatherChild} \bowtie \text{motherChild}$$

```
select fc.child, fc.father, mc.mother
from   motherChild mc, fatherChild fc
where  fc.child = mc.child
```


Exercise 4: Join and Other Operations

"Persons that earn more than their father,
showing name, income, and income of the father"

Write the query both in relational algebra and SQL

Exercise 5: Solution

"Persons that earn more than their father,
showing name, income, and income of the father"

$\pi_{name,\ income,\ IF}\ (\sigma_{income>IF}$

$(\rho_{FN \leftarrow name,\ FA \leftarrow age,\ FI \leftarrow income}(person)$

$\bowtie_{FN=father}$

$(fatherChild \bowtie_{child=name}\ person)))$

```
select f.name, f.income, c.income
from   person f, fatherChild fc, person c
where  f.name = fc.father and
       fc.child = c.name and
       c.income > f.income
```


`select`, with Renaming of the Result

For the persons that earn more than their father, show their name, income, and the income of the father

```
select fc.child, c.income as income,
       f.income as incomefather
from   person f, fatherChild fc, person c
where  f.name = fc.father and
       fc.child = c.name and
       c.income > f.income
```

Explicit Join

For every person, return the person, their father and their mother

```
select fatherChild.child, father, mother
from   motherChild, fatherChild
where  fatherChild.child = motherChild.child
```

```
select fatherChild.child, father, mother
from   motherChild join fatherChild on
       fatherChild.child = motherChild.child
```


`select` with Explicit Join, Syntax

```
select ...
from   Table { join Table on JoinCondition }, ...
[where OtherCondition ]
```

Exercise 6: Explicit Join

"For the persons that earn more than their father, show their name, income, and the income of the father"

Express the query in SQL, using an explicit join

Exercise 6: Solution

"For the persons that earn more than their father, show their name, income, and the income of the father"

```
select c.name, c.income, f.income
from   person c
          join fatherChild fc on c.name = fc.child
          join person f on fc.father = f.name
where  c.income > f.income
```

An equivalent formulation without explicit join:

```
select c.name, c.income, f.income
from   person c, fatherChild fc, person f
where  c.name = fc.child and
       fc.father = f.name and
       c.income > f.income
```

A Further Extension: Natural Join (Less Frequent)

"Return the names of fathers, mothers, and their children"

$$\pi_{father,mother,child}\,(fatherChild \bowtie motherChild)$$

In SQL:

```
select father, mother, fatherChild.child
from   motherChild join fatherChild on
          fatherChild.child = motherChild.child
```

Alternatively:

```
select father, mother, fatherChild.child
from   motherChild natural join fatherChild
```


Outer Join

"For every person, return the father and, if known, the mother"

```
select fatherChild.child, father, mother
from   fatherChild left outer join motherChild
       on fatherChild.child = motherChild.child
```

Note: "`outer`" is optional

```
select fatherChild.child, father, mother
from   fatherChild left join motherChild
       on fatherChild.child = motherChild.child
```

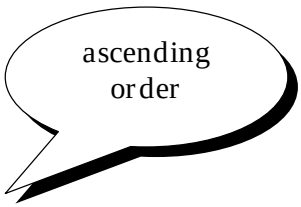
Outer Join: Examples

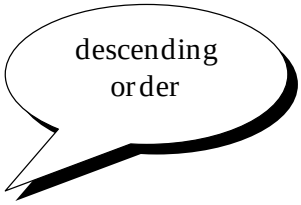
```
select fatherChild.child, father, mother
from   motherChild join fatherChild
       on motherChild.child = fatherChild.child

select fatherChild.child, father, mother
from   motherChild left outer join fatherChild
       on motherChild.child = fatherChild.child

select fatherChild.child, father, mother
from   motherChild right outer join fatherChild
       on motherChild.child = fatherChild.child

select fatherChild.child, father, mother
from   motherChild full outer join fatherChild
       on motherChild.child = fatherChild.child
```


Ordering the Result: `order by`

"Return name and income of persons under thirty, in alphabetic order of the names"

```
select name, income
from   person
where  age < 30
order by  name

select name, income
from   person
where  age < 30
order by  name desc
```





Ordering the Result: `order by`

```
select name, income
from   person
where  age < 30
```

name	income
Andy	21
Rob	15
Mary	42

```
select name, income
from   person
where  age < 30
order by name
```

name	income
Andy	21
Mary	42
Rob	15

Aggregate Operators

Among the expressions in the target list, we can also have expressions that calculate values based on multisets of tuples:

- count, minimum, maximum, average, sum

Basic Syntax (simplified):

Function ([`distinct`] *ExpressionOnAttributes*)

Aggregate Operators: `count`

Syntax:

- counts the number of tuples:

  `count (*)`

- counts the values of an attribute (considering duplicates):

  `count (`*Attribute*`)`

- counts the distinct values of an attribute:

  `count (distinct` *Attribute*`)`

Aggregate Operator `count`: Example

Example: How many children has Frank?

```
select count(*) as NumFranksChildren
from   fatherChild
where  father = 'Frank'
```

Semantics: The aggregate operator (`count`), which counts the tuples, is applied to the result of the query:

```
select *
from   fatherChild
where  father = 'Frank'
```

Results of `count`: Example

fatherChild

father	child
Steve	Frank
Greg	Kim
Greg	Phil
Frank	Andy
Frank	Rob

NumFranksChildren
2

`count` and Null Values

```
select count(*)
from   person
```

Result = number of tuples = 4

```
select count(income)
from   person
```

Result = number of values different from NULL = 3

```
select count(distinct income)
from   person
```

Result = number of distinct values (excluding NULL) = 2

person

name	age	income
Andy	27	21
Rob	25	NULL
Mary	55	21
Anne	50	35

Other Aggregate Operators

`sum`, `avg`, `max`, `min`

- argument can be an attribute or an expression (but not "*")
- `sum` and `avg`: numerical and temporal arguments
- `max` and `min`: arguments on which an ordering is defined

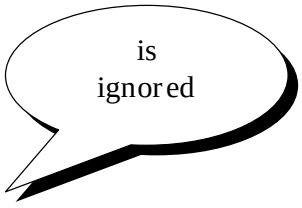
Example: Average income of Frank's children

```
select avg(p.income)
from   person p join fatherChild fc on
       p.name = fc.child
where  fc.father = 'Frank'
```


Aggregate Operators and Null Values

```
select avg(income) as meanIncome
from   person
```

person	name	age	income
	Andy	27	30
	Rob	25	NULL
	Mary	55	36
	Anne	50	36



meanIncome
34

Aggregate Operators and the Target List

An incorrect query (whose name should be returned?):

```
select name, max(income)
from   person
```

The target list has to be homogeneous, for example:

```
select min(age), avg(income)
from   person
```


Aggregate Operators and Grouping

- Aggregation functions can be applied to partitions of the tuples of a relations
- To specify the partition of tuples, on uses the `group by` clause:

`group by` *attributeList*

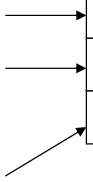
Aggregate Operators and Grouping

The number of children of every father.

```
select father, count(*) as NumChildren
from   fatherChild
group by father
```

fatherChild

father	child
Steve	Frank
Greg	Kim
Greg	Phil
Frank	Andy
Frank	Rob



father	NumChildren
Steve	1
Greg	2
Frank	2

Semantics of Queries with Aggregation and Grouping

1. The query is run ignoring the `group by` clause and the aggregate operators:

   ```
   select *
   from   fatherChild
   ```

2. The tuples that have the same value for the attributes appearing in the `group by` clause, are grouped into equivalence classes.

3. Each group contributes a tuple to the answer. The tuple consists of the values of the `group by` attributes and the result of applying the aggregation function to the group.

Exercise 7: `group by`

"For each group of adult persons who have the same age, return the maximum income for every group and show the age"

Write the query in SQL!

person	name	age	income

Exercise 7: Solution

"For each group of adult persons who have the same age, return the maximum income for every group and show the age"

```
select age, max(income)
from   person
where  age > 17
group by age
```

Grouping and Target List

In a query that has a `group by` clause, only such attributes can appear in the target list (except for aggregation functions) the appear in the `group by` clause.

Example: Incorrect: income of persons, grouped according to age

```
select age, income
from   person
group by age
```

There could exist several values for the same group.

Correct: average income of persons, grouped by age.

```
select age, avg(income)
from   person
group by age
```


Grouping and Target List (cntd)

The syntactic restriction on the attributes in the select clause holds also for queries that would be semantically correct (i.e., for which there is only a single value of the attribute for every group).

Example: Fathers with their income and with the average income of their children.

Incorrect:

```
select fc.father, avg(c.income), f.income
from   person c join fatherChild fc on c.name=fc.child
               join person f on fc.father=f.name
group by fc.father
```

Correct:

```
select fc.ather, avg(c.income), f.income
from   person c join fatherChild fc on c.name=fc.child
               join person f on fc.father=f.name
group by fc.father, f.income
```

Conditions on Groups

It is also possible to filter the groups using selection conditions.

Clearly, the selection of groups differs from the selection of the tuples in the `where` clause: the tuples form the groups.

To filter the groups, the “having clause” is used.

The having clause must appear after the “`group by`”

Example: Fathers whose children have an average income greater 25.

```
select fc.father, avg(c.income)
from   person c join fatherChild fc
       on c.name = fc.child
group by fc.father
having avg(c.income) > 25
```


Exercise 8: `where` or `having`?

“Fathers whose children under age 30 have an average income greater 20”

Exercise 8: Solution

"Fathers whose children under the age of 30 have an average income greater 20"

```
select father, avg(f.income)
from   person c join fatherChild fc
       on c.name = fc.child
where  c.age < 30
group by cf.father
having avg(c.income) > 20
```


Syntax of SQL `select` (Summary)

SQLSelect ::=

`select` *ListOfAttributesOrExpressions*
`from` *ListOfTables*
[`where` *ConditionsOnTuples*]
[`group by` *ListOfGroupingAttributes*]
[`having` *ConditionsOnAggregates*]
[`order by` *ListOfOrderingAttributes*]

Union, Intersection, and Difference

Within a `select` statement one cannot express unions.

An explicit construct is needed:

```
select ...
union [all]
select ...
```

WIth `union`, duplicates are eliminated (also those originating from projection).

WIth `union all` duplicates are kept.

Positional Notation of Attributes

```
select father, child
from   fatherChild
union
select mother, child
from   motherChild
```

Which are the attribute names of the result?

Those of the first operand!

→ SQL matches attributes in the same position

→ SQL renames the attributes of the second operand

Result of the Union

father	child
Greg	Frank
Greg	Kim
Greg	Phil
Frank	Andy
Frank	Rob
Lisa	Mary
Lisa	Greg
Anne	Kim
Anne	Phil
Mary	Andy
Mary	Rob

Positional Notation: Example

```
select father, child
from   fatherChild
union
select mother, child
from   motherChild
```

```
select father, child
from   fatherChild
union
select child, mother
from   motherChild
```

Positional Notation (cntd)

Renaming does not change anything:

```
select father as parent, child
from   fatherChild
union
select child, mother as parent
from   motherChild
```

Correct (if we want to treat fathers and mothers as parents):

```
select father as parent, child
from   fatherChild
union
select mother as parent, child
from   motherChild
```


Difference

```
select name
from   employee
except
select lastName as name
from   employee
```

We will see that differences can also be expressed with nested `select` statements.

Intersection

```
select name
from   employee
intersect
select lastName as name
from   employee
```

is equivalent to

```
select en.name
from   employee en, employee eln
where  en.name = eln.lastName
```


Single Block Queries: Exercises

Consider a database about suppliers and parts with the following schema:

```
Supplier(sid, sname, address)
Part(pid, pname, colour)
Catalog(sid, pid, cost)
```

Formulate the following queries in SQL:

1. Find the names of suppliers who supply some red part.
2. Find the IDs of suppliers who supply some red or green part.
3. Find the IDs of suppliers who supply some red part and are based at 21 George Street.

Single Block Queries: Exercises (cntd)

4. Find the names of suppliers who supply some red part or are based at 21 George Street.
5. Find the IDs of suppliers who supply some red and some green part.
6. Find pairs of IDs such that for some part the supplier with the first ID charges more than the supplier with the second ID.
7. For each supplier, return the maximal and the average cost of the parts they offer.
8. List those red parts that on average cost no more than 30 Euro.
9. List the names of those red parts that are offered by at least three suppliers.

Nested Queries

- In the atomic conditions of the `where` clause one can also use a `select` clause (which must appear in parentheses).

- In particular, in atomic conditions one can have:
  - comparisons of an attribute (or several attributes) with the result of a subquery
  - existential quantification

Nested Queries (Example)

"Name and income of Frank's father"

```
select  f.name, f.income
from    person f, fatherChild fc
where   f.name = fc.father and fc.child = 'Frank'
```

```
select  f.name, f.income
from    person f
where   f.name = (select fc.father
                  from   fatherChild fc
                  where  fc.child = 'Frank')
```


Nested Queries: Operators

In the `where` clause, the result of a nested query can be related to other values by way of several `operators`:

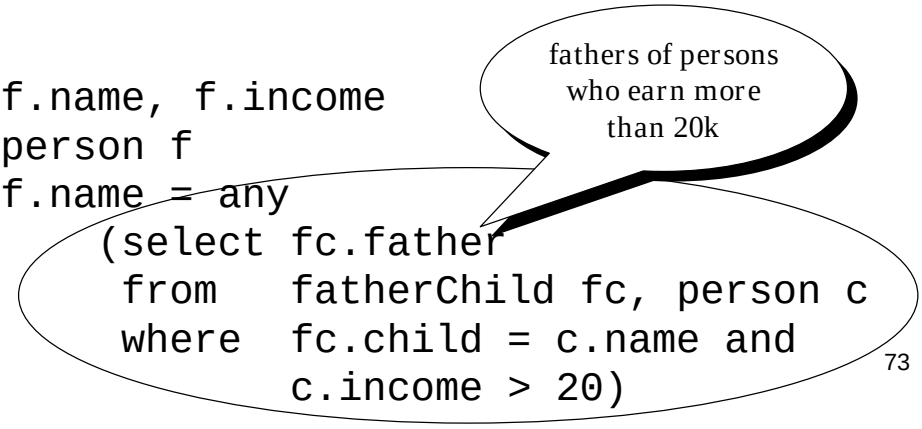
- equality and other comparisons (the result of the nested query must be unique)
- if it is not certain that the result of the nested query is unique, the nested query can be preceded by one of the keywords:
  - `any`: true, if the comparison is true for at least `one` of the result tuples of the nested query
  - `all`: true, if the comparison is true for all the result tuples of the nested query
- the operator`in`, which is equivalent to `=any`
- the operator`not in`, which is equivalent to `<>all`
- the operator `exists`

Nested Queries: Example

Name and income of the fathers of persons who earn more than 20k.

```
select distinct f.name, f.income
from   person f, fatherChild fc, person c
where  f.name = fc.father and
       fc.child = c.name and c.income > 20
```

```
select f.name, f.income
from   person f
where  f.name = any
         (select fc.father
          from   fatherChild fc, person c
          where  fc.child = c.name and
                 c.income > 20)
```

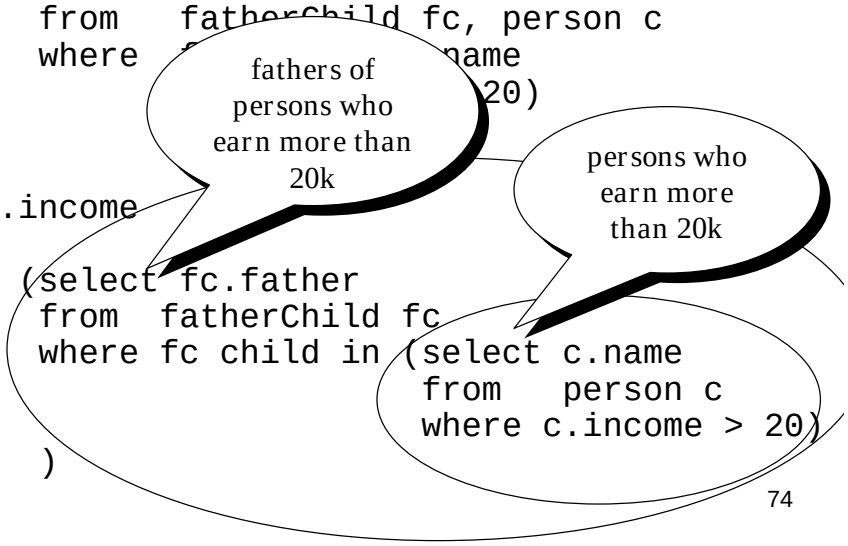


Nested Queries: Example

Name and income of the fathers of persons who earn more than 20k.

```
select f.name, f.income
from   person f
where  f.name in (select fc.father
                  from   fatherChild fc, person c
                  where  f          name
                                    20)
```

```
select f.name, f.income
from   person f
where  f.name in (select fc.father
                  from  fatherChild fc
                  where fc child in (select c.name
                                     from   person c
                                     where c.income > 20)
                  )
```



Nested Queries: Comments

- The nested formulation of a query is usually executed less efficiently than an equivalent unnested formulation (due to limitations of the query optimizer).
- The nested formulation is sometimes more readable.
- The subqueries cannot contain set operators ("union is only performed at the top level"), but this is not a significant limitation.

Nested Queries: Example with `all`

"Persons who have an income that is higher than the income of all persons younger than 30"

Nested Queries: Example with `all`

"Persons who have an income that is higher than the income of all persons younger than 30"

```
select name
from   person
where  income >= all (select income
                      from   person
                      where  age < 30)
```


Equivalent Formulation with `max`

"Persons who have an income that is higher than the income of all persons younger than 30"

```
select name
from   person
where  income >= (select max(income)
                  from   person
                  where  age < 30)
```

Nested Queries: Example with `exists`

An expression with the operator `exists` is true if the result of the subquery is not empty.

Example: “Persons with at least one child”

```
select *
from   person p
where  exists (select *
               from  fatherChild fc
               where fc.father = p.name)
       or
       exists (select *
               from  motherChild mc
               where mc.mother = p.name)
```

Note: the attribute `name` refers to the table in the outer `from` clause.

Nesting, Union, and “or”

The query for “persons with at least one child” can also be expressed as a union:

```
select p.name, p.age, p.income
from   person p, fatherChild fc
where  fc.father = p.name
union
select p.name, p.age, p.income
from   person p, motherChild mc
where  mc.mother = p.name
```

Does the following query with “or” return the same answers?

```
select distinct p.name, p.age, p.income
from   person p, fatherChild fc, motherChild mc
where  fc.father = p.name
         or mc.mother = p.name
```

Nested Queries and Negation

All the queries with nesting in the previous examples are equivalent to some unnested query. So, what's the point of nesting?

Example: "Persons without a child"

```
select *
from   person p
where  not exists (select *
                   from  fatherChild fc
                   where fc.father = p.name)
       and
       not exists (select *
                   from  motherChild mc
                   where mc.mother = p.name)
```

This cannot be expressed equivalently as a "`select from where`" query.

Why?

Exercise 9

"Name and age of the mothers all of whose children are at least 18"

Approach 1: Subquery with `all`

Approach 2: Subquery with `min`

Approach 3: Subquery with `not exists`

Exercise 9: Solution with `all`

"Name and age of the mothers all of whose children are at least 18"

```
select m.name, m.age
from   person m join motherChild mc
                on m.name = mc.mother
where  18 =< all (select c0.age
                  from   motherChild mc0 join person c0
                                 on mc0.mother = c0.name
                  where  mc0.mother = mc.mother)
```


Exercise 9: Solution with `min`

"Name and age of the mothers all of whose children are at least 18"

```
select m.name, m.age
from   person m join motherChild mc
                on m.name = mc.mother
where  18 =< (select min(c0.age)
              from   motherChild mc0 join person c0
                             on mc0.mother = c0.name
              where  mc0.mother = mc.mother)
```

"Name and age of mothers where the minimal age of their children is greater or equal 18"

Exercise 9: Solution with `not exists`

"Name and age of the mothers all of whose children are at least 18"

```
select m.name, m.age
from   person m join motherChild mc
                 on m.name = mc.mother
where  not exists
             (select *
              from   motherChild mc0 join person c0
                            on mc0.mother = c0.name
              where  mc0.mother = mc.mother and
                     c0.age < 18)
```

Name and age of mothers who don't have a child that is younger than 18.

Nested Queries: Comments

- Visibility rules:
  - it is not possible to refer to a variable defined in a block below the current block
  - if an attribute name is not qualified with a variable or table name, it is assumed that it refers to the "closest" variable or table with that attribute
- In each block, one can refer to variables defined in the same block or in surrounding blocks
- Semantics: the inner query is executed for every tuple of the outer query

Exercise

On the supplier and parts DB:

```
Supplier(sid, sname, address)
Part(pid, pname, colour)
Catalog(sid, pid, cost)
```

1. Suppliers that supply *only* red parts

2. Suppliers that supply *all* red parts

Nested Queries: Visibility

persons having at least one child.

```
select *
from   person
where  exists (select *
               from  fatherChild
               where father = name)
       or
       exists (select *
               from  motherChild
               where mother = name)
```

The attribute `name` refers to the table `person` in the outer `from` clause.

More on Visibility

Note: This query is incorrect:

```
select *
from  employee
where dept in (select name
               from  department D1
               where name = 'Production')
      or
      dept in (select name
               from  department D2
               where D2.city = D1.city)
```

employee	name	lastName	dept

department	name	address	city

Visibility: Variables in Internal Blocks

Name and income of the fathers of persons who earn more than 20k, showing also the income of the child.

```
select distinct f.name, f.income, c.income
from   person f, fatherChild, person c
where  f.name = fc.father and fc.child = c.name
       and c.income > 20
```

In this case, the “intuitive” nested query is incorrect:

```
select name, income, c.income
from   person
where  name in (select father
                from fatherChild
                where child in (select name
                                from person c
                                where c.income > 20))
```

Correlated Subqueries

It may be necessary to use in inner blocks variables that are defined in outer blocks. In this case one talks about correlated subqueries.

Example: The fathers all of whose children earn strictly more than 20k.

```
select distinct fc.father
from   fatherChild fc
where  not exists (select *
                   from  fatherChild fc0, person c
                   where fc.father = fc0.father
                         and fc0.child = c.name
                         and c.income <= 20)
```


Exercise 10: Correlated Subqueries

"Name and age of mothers who have a child whose age differs less than 20 years from their own age"

Exercise 10: Solution

"Name and age of mothers who have a child whose age differs less than 20 years from their own age"

```
select m.name, m.age
from   person m, motherChild mc
where  m.name = mc.mother and
       mc.child in (select c.name
                    from   person c
                    where  m.age – c.age < 20)
```


Question: Intersection

Can one express intersection by way of nesting?

```
select name from employee
  intersection
select lastName as name from employee
```

Intersection by Way of Nesting

```
select name from employee
  intersection
select lastName as name from employee


select name
from  employee
where name in (select lastName
               from   employee)

select name
from  employee e
where exists (select *
              from   employee
              where  lastName = e.name)
```


Intersection Without Nesting

Is it possible to express intersection without nesting?

```
select name from employee
  intersection
select lastName as name from employee
```

Exercise 11

Can one express set difference by way of nesting?

```
select name from employee
  except
select lastName as name from employee
```


Exercise 11 (Solution 1)

Can one express set difference by way of nesting?

```
select name from employee
  except
select lastName as name from employee
```

```
select name
from  employee
where name not in (select lastName
                   from employee)
```

Exercise 11 (Solution 2)

Can one express set difference by way of nesting?

```
select name from employee
  except
select lastName as name from employee
```

```
select name
from   employee e
where  not exists (select *
                   from  employee
                   where lastName = e.name)
```


Exercise 12: Nesting and Functions

“The person (or the persons) that have the highest income”

Exercise 12: Solution

"The person (or the persons) that have the highest income"

```
select *
from  person
where income = (select max(income)
                from   person)
```

Or:

```
select *
from  person
where income >= all (select income
                     from   person)
```


Nested Queries: Conditions on Several Attributes

The persons which have a unique combination of age and income

(that is, persons for whom the pair (age, income) is different from the corresponding pairs of all other persons).

```
select *
from  person p
where (age,income) not in
                     (select age, income
                      from person
                      where name <> p.name)
```

Views

- A view is a table whose instance is derived from other tables by a query.

  `create view` *ViewName* `[(`*AttributeList*`)] as` *SQLSelect*

- Views are virtual tables: their instances (or parts of them) are only calculated when they are used (for instance in other queries).

Example:

```
create view AdminEmp(empNo,firstName,lastName,sal) as
  select EmpNo, firstName, lastName, salary
  from   employee
  where  dept = 'Administration' and
         salary > 10
```


A Non-standard Query

- "Which age group has the highest total income?"

- One solution is to use nesting in the `having` clause:

```
select age
from   person
group by age
having sum(income) >= all (select sum(income)
                           from   person
                           group by age)
```

- Another solution is to create a view.

Solution with Views

```
create view ageIncome(age,sumIncome) as
   select age, sum(income)
   from   person
   group by age


select age
from   ageIncome
where  sumIncome = (select max(sumIncome)
                    from   ageIncome)
```


Exercise 13

- Among all companies based in George Street that sell red parts, which is the one with the least average price for red parts?

Exercise 13 (Solution)

- Among all companies based in George Street that supply red parts, which is the one with the least average price for red parts?

```
create view RedPartCompGS(sid,name,avgCost) as
 select sid, name, avg(cost)
 from   supplier natural join catalog
                 natural join part
 where  address LIKE '%George St%' AND
        colour = 'red'
 group by sid, name
```


Exercise 13 (Solution, cntd)

- Among all companies based in George Street that sell red parts, which is the one with the least average price for red parts?

```
select name
from   RedPartCompGS
where  avgCost = (select max(avgCost)
                  from   RedPartCompGS)
```

References

In preparing the lectures I have used several sources.
The main ones are the following:

Books:

- A First Course in Database Systems, by J. Ullman and J. Widom
- Fundamentals of Database Systems, by R. Elmasri and S. Navathe

Slides:

- The slides of this chapter are mostly translations of material prepared by Maurizio Lenzerini (University of Rome, “La Sapienza”) and Diego Calvanese (Free University of Bozen-Bolzano) for their introductory course on databases at the University of Rome, “La Sapienza”